FLUID DYNAMICS

Phase Separation Simulations using Annular Centrifugal Contactors

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Annular centrifugal contactors are apparati consisting of two concentric cylindrical zones. The spinning rotor and the stationary housing wall form the external annular zone. Typically, an aqueous and an organic phase are rapidly dispersed in this mixing zone. Upon mixing, solutes can be transferred from one phase to the other facilitating recovery. After mixing, the two-phase flow enters the inner rotating cylinder through an annular opening in the bottom. In this zone, the phases are separated by high centrifugal forces and each liquid leaves the device through tangential exit ports on top. Figure 1 shows a cutaway view of the centrifugal contactors used at Los Alamos National Laboratory for actinide recovery.

Our goal is to use the advanced multiphase flow simulation tools of T-3 to evaluate and optimize advanced designs for contactors of the Actinide Process Chemistry group (NMT-2). CartaBlanca is the multiphase flow solver used in this simulation.

As a first step, we simulate the hydraulics of the separation zone. Figure 2 shows a mesh of a quarter of the separation zone and a simplified outlet zone. In this simulation, the lighter fluid (fluid 2, organic) leaves through one small opening at the center of the outside wall of the central cylindrical region at the top. The heavier fluid (fluid 1, aqueous) leaves through another small opening, also at the center of the outside wall of the external cylindrical region at the top.

We studied the behavior of a mixture, with a ratio of organic to aqueous material equal to one, entering the device at a rate of 500 mL/minute. The density of the aqueous fluid is 1.025 g/cm^3 and the density of the organic fluid is 0.8175 g/cm^3. The drag time constant used in the calculation was 1.95e-3 seconds. This value was determined by empirically matching experimental data.

Figure 3 shows the aqueous phase density distribution on a plane through the center of the quarter mesh for the rotor speeds of 500 rpm, 1000 rpm, 1500 rpm, and 3000 rpm.

*Figure 1—
Cutaway view of the
centrifugal contactors
used at Los Alamos
National Laboratory for
actinide recovery.*
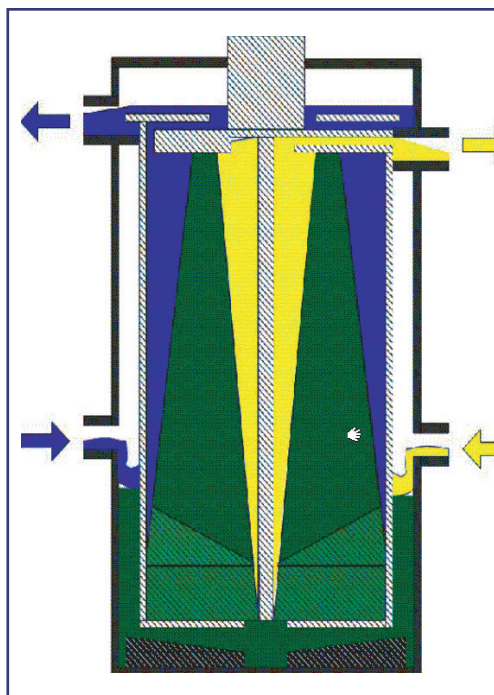
*Figure 2—
Mesh of the separation
zone.*

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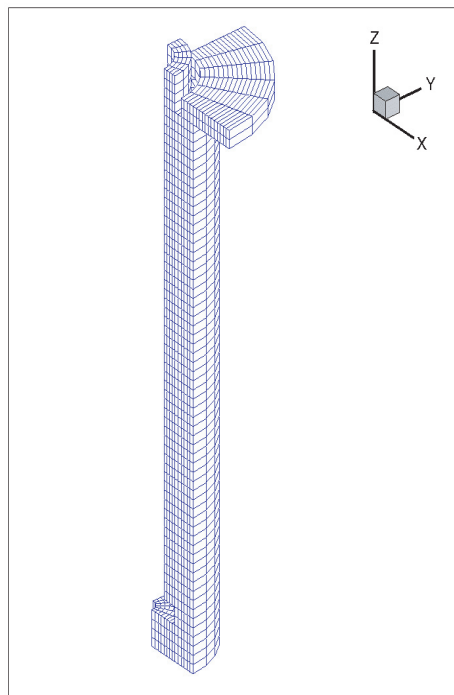
As the rotation rate is reduced, the effective separation diminishes as expected. At 500 rpm, it is possible to see a cone-like density distribution seen also in the idealized drawing in Fig. 1.

In Table 1, we show the contamination of both phases when they leave the device.

Table 1—
Phase contamination at the outlets.

Rotor Speed (rpm)	Organic Phase in Aqueous Stream	Aqueous Phase in Organic Stream
500	Less than 0.01%	Up to 40%
1000	Non-discernible	Up to 15%
1500	Non-discernible	Up to 4%
3000	Non-discernible	Less than 0.4%
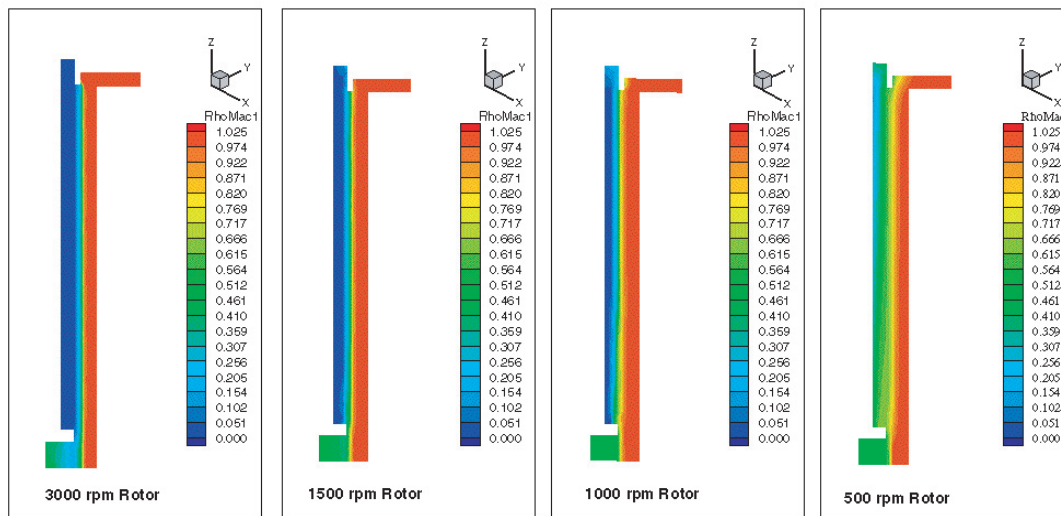
Figure 3—
Aqueous phase density for different rotor velocities.

This table compares qualitatively with the experimental data collected in the Nuclear Materials Technology (NMT) laboratories. These results are encouraging to us, as they seem to show that we have captured the essence of the hydraulic phenomena of the separators in a three-dimensional simulation. As noted in previous reports, we have built into our simulation the capability to simulate the mass transfer of solute between phases and the ability to represent internals such as vanes using a particle technique. We believe that we can continue our progress toward a journal publication detailing our results and further refinements of our simulation capabilities ultimately to provide a tool for process and unit optimization.

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